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Effect of phenological change in ornamental plants on the dates of spring outings to popular locations, Beijing, China

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ABSTRACT: We investigated the influences of changes in the flowering dates of ornamental plants on the dates of visitors' spring outings. We collected messages (2010–2014) posted on Sina Weibo (one of the most popular social networks in China) as an indicator of the number of visitors per 10 d period for 5 popular locations in Beijing, China. Subsequently, we compared the flowering duration with visitor high seasons for these locations. Results showed that visitors adjusted their plans to see the flowers in accordance with the phenology for locations with specific ornamental plants. However, for locations with multiple ornamental plants, visitors used their experience rather than phenological change to plan outings, because there were always flowering plants to see in the spring. Interannual changes in the flowering date of ornamental plants were mainly triggered by temperature changes. Our results clearly revealed that the visitors' responses were connected to climate-induced flowering phenological change, especially in locations focusing on 1 species.

KEY WORDS: Flowering phenology · Ornamental plants · Human response · High season

1. INTRODUCTION

Flowering seasons of ornamental plants (i.e. plants that are grown for decorative purposes in gardens and landscape design projects) have important aesthetic and economic benefits for many regions of the world. For example, cherry blossoms have great spiritual significance and extensive popularity in Japan (McClellan 2013). Similarly, the National Cherry Blossom Festival which takes place during April in Washington, DC attracts millions of visitors (Chung et al. 2011). In China, more than 0.8 million people visited the Beijing Botanical Garden during the peach *Amygdalus persica* blossom festival (Ma & Fang 2006). Selecting appropriate dates on which to hold these cultural events is of great importance to their success (Sparks et al. 2012).

Due to global warming, the first flowering date, peak flowering date and flowering duration of ornamental plants have changed markedly over recent decades. For example, most time-series of first flowering dates ending after the mid-1980s had tendencies towards earlier flowering in north-temperate Sweden (Bolmgren et al. 2013). Similar results were also found in East Asia (Miller-Rushing et al. 2007, Dai et al. 2013). In Guernsey, UK, flowering duration of garden plants has shortened by an average rate of 10 d decade^{-1} from 1985–2011 (Bock et al. 2014). These changes in plant phenology have been unequivocally attributed to temperature increase (Fu et al. 2015).

Since the flowering dates of ornamental plants have clearly shifted and vary greatly among years, we wondered whether phenological changes have

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also affected human spring activities. Usually, people have 2 choices when planning spring outings; either based on their experience or on climate conditions and flowering dates. On the first basis, they would visit at a relatively fixed date each year, while on the second basis, they would not. Furthermore, the blossom festival dates determined by organizers may also affect plans for spring outings.

In this study, 5 locations in Beijing, China were selected as representative destinations for investigating visitors' responses. High seasons (i.e. the periods with most visitors) of these locations from 2010–2014 were identified based on data from social media and then compared to the flowering period of corresponding plants and blossom festival dates. The impact of temperature on flowering phenophases was examined using long-term phenological and temperature data. Overall, the objective of this study was to examine whether, and how, the public responds to spring flowering dates.

2. MATERIALS AND METHODS

2.1. Study area

Beijing has a typical temperate monsoon climate with a mean annual temperature of 12.9°C (1981–2010). Mean temperatures of the warmest and coldest months are 26.7°C (July) and –3.1°C (January), respectively. Annual mean precipitation is 532 mm, 78.6% of which occurs during summer and early autumn (June–September).

In Beijing, spring is the best season for admiring the sights of blooming flowers, because most of the plants begin to flower in April (Bai et al. 2011). We selected 5 famous attractions for visitors to see flowering trees: Yuyuantan Park, Jingshan Park, City Wall Relics Park, Summer Palace and Beijing Botanical Garden (Table 1). These locations can be grouped into 2 types: the first 3 are locations with specific ornamental plants, while the last 2 have multiple ornamental plants. In the first group, we expected the dates of visits to change in accordance with the flowering period. For the second group, we hypothesized that the dates of visits would not change, because plants bloom throughout the spring.

2.2. Data

2.2.1. Phenological and meteorological data

Phenological data were gathered by the China Phenological Observation Network. The first flowering date (FFD) and the end of flowering date (EFD) of 49 ornamental plants have been observed at the Summer Palace from 1963–2014. FFD is defined as the date when at least 1 fresh flower was present in any cluster of the whole plant. EFD is the date when the majority of petals have fallen. The period between FFD and EFD can be regarded as flowering duration. Daily mean temperatures were obtained from Beijing Meteorological Service Center. In addition, we recorded the cherry blossom festival dates at Yuyuantan Park, and peony blossom festival dates at Jingshan Park from the Yearbook of Beijing's Parks.

2.2.2. Number of visitors

Since ticket data from the 5 locations were unavailable, we collected data from social media (Sina Weibo; http://weibo.com/) as an indicator of

Table 1. Summary of 5 locations for spring flowers in Beijing

Locations	Position	Area (ha)	Characteristics	Observed species
Yuyuantan Park	39° 54′ 53″ N, 116° 18′ 53″ E	136	China's largest cherry garden with over 2000 cherry *Prunus* spp. trees. The cherry blossom festival has been held there every year since 1989	*Prunus yedoensis*
Jingshan Park	39° 55′ 27″ N, 116° 23′ 25″ E	23	Peonies have been displayed here since the Yuan Dynasty (1271–1368). The peony blossom festival has been held since 1997	*Paeonia suffruticosa*
City Wall Relics Park	39° 58′ 26″ N, 116° 22′ 37″ E	126	The largest number of Chinese flowering crab apples *Malus* spp. in Beijing	*Malus micromalus*
Summer Palace	39° 58′ 48″ N, 116° 16′ 03″ E	290	As a royal garden in the Qing Dynasty (1616–1921), many ornamental plants were grown there. One of the most famous is Yulan Magnolia *Magnolia denudata*	49 species
Beijing Botanical Garden	39° 59′ 33″ N, 116° 12′ 19″ E	400	More than 3000 plants species are grown here, including peach *Amygdalus davidiana* and Chinese plum *Armeniaca mume*	49 species

the number of visitors. Sina Weibo is an online social networking service that enables users to post quick and frequent messages. It is one of the most popular social network websites in China, in use by over 30% of internet users. On the Sina Weibo website, we used the name of the 5 locations as keywords and retrieved messages related to spring outings. As Sina Weibo was established in August 2009, we could only gather spring data since 2010. The number of messages per 10 d period from January to June was counted for each location from 2010–2014.

Messages were included in our counts only if they clearly indicated that the author had been to the location on a specific date. Messages were excluded under the following conditions: (1) just introduced the location; (2) authors said that they wanted to go to the location rather than had been there; (3) other irrelevant messages (e.g. a movie also called the Summer Palace); (4) someone visited a location but did not post immediately. Examples of a valid and an invalid message are shown in Fig. S1 in the Supplement at www.int-res.com/articles/suppl/c072p177_supp.pdf. More than 39000 messages were extracted (Table 2). Data for the City Wall Relics Park in 2010 were excluded because of too few messages.

The only available data on the actual number of visitors were the monthly totals for 221 tourist attractions (including our 5 locations) in Beijing from 2010–2014, acquired from the Beijing Statistical Information Net (www.bjstats.gov.cn/English/). Monthly changes in the number of Weibo messages accurately tracked the actual number of visitors from January to April (Fig. S2). However, the number of visitors declined less than the Weibo data in May and June, because the actual visitor data included all Beijing attractions, while the Weibo data were restricted to the 5 attractions characterized by spring flowers. Therefore, the Weibo data could, to a certain degree, reflect the true number of visitors in spring.

Table 2. Number of messages posted on Sina Weibo for each location between January and June from 2010–2014

Year	Yuyuantan Park	Jingshan Park	City Wall Relics Park	Summer Palace	Beijing Botanical Garden	Total
2010	389	117	48	541	146	1241
2011	775	742	306	2782	558	5163
2012	2890	2090	458	4097	1482	11017
2013	3475	2099	502	4946	2006	13028
2014	2340	1002	255	4139	1038	8774
Total	9869	6050	1569	16505	5230	39223

2.3. Statistical analyses

2.3.1. Comparison among high season, flowering phenology and festival dates

Since the number of messages was different among years (Table 2), we first used unity-based normalization to bring all values into the range [0, 1] for each year and location:

$$X' = \frac{X - X_{min}}{X_{max} - X_{min}} \quad (1)$$

where X is the number of messages per 10 d period from January to June, $X_{max.}$ and $X_{min.}$ are the maximum and minimum values of the number of messages, respectively and X' is the normalized value.

Subsequently, we determined the high season for each location at each year. Here, the high season was defined as the time of year when the greatest number of visits was made. The consecutive n-point period in the time series of X' with the maximum sum was determined as the high season. The value of n for each location was determined as the number of points whose X' values were >0.5 (in at ≥3 years).

For locations with specific ornamental plants, we compared the interannual variation in flowering duration of the corresponding species with the high season. The corresponding species at Yuyuantan Park, Jingshan Park and City Wall Relics Park were *Prunus yedoensis*, *Paeonia suffruticosa* and *Malus micromalus*, respectively (Table 1). Furthermore, the dates of 2 established blossom festivals at Yuyuantan Park and Jingshan Park, determined by organizers, were also compared.

For locations with multiple ornamental plants (Summer Palace and Beijing Botanical Garden), we compared the interannual variation in high season with the best period for seeing spring flowers. The best period for seeing spring flowers was defined through the following steps: (1) the number of species in flower at the Summer Palace was counted daily for all 49 monitored species (Fig. 1), (2) a threshold was defined as the midpoint between the minimum and maximum number of species in flower, and the best period was defined as when the number exceeded the threshold. This equated to *Salix matsudana* FFD for the start and *Robinia pseudoacacia* FFD for the end of the best period (Fig. 1).

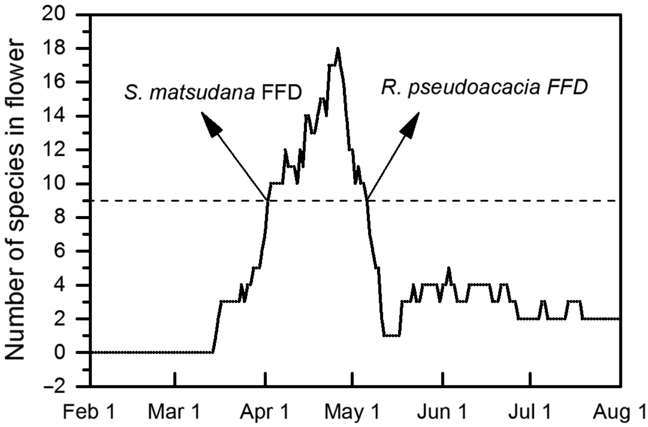

Fig. 1. Number of monitored species in flower at the Summer Palace; the best period for seeing spring flowers is defined as from the first flowering date of *Salix matsudana* to the first flowering date of *Robinia pseudoacacia*. Horizontal dashed line: midpoint between the minimum and maximum number of species in flower

2.3.2. Relationship between flowering phenology and temperature

In order to investigate the relationship between flowering phenology and temperature, we first estimated the length of the preseason during which temperature affected phenological events most significantly (Matsumoto et al. 2003, Dai et al. 2013). For the FFD of our specific plants, the preseason was defined as the period (in 15 d steps) before the mean FFD, for which the correlation coefficient between FFD and mean temperature was highest during 1963–2014. Regarding EFD, the start date of the preseason was the same as that of FFD, but the end date was defined as the mean EFD. With respect to the best period for seeing spring flowers, the preseason was defined using *S. matsudana* and *R. pseudoacacia* FFD data. Temperature sensitivity was estimated from the slope of linear regression of the phenological dates on mean preseason temperature.

3. RESULTS

3.1. Relationship between flowering phenology and high season

At Yuyuantan Park, the number of visitors reached a peak during spring in each year, varying from late March to mid-April (see Fig. S3 in the Supplement at www.int-res.com/articles/suppl/c072p177_supp.pdf). The high season lasted about 1 mo, which was longer than the flowering duration of *Prunus yedoensis* (12 d) because other early-blossom cherry species were also planted there. During 2010–2014, the high season generally coincided with the interannual changes in flowering duration of *P. yedoensis* (Fig. 2a), especially in 2 early-blooming years (2011 and 2014). Except for 2013, the flowering duration of *P. yedoensis* and high season also coincided with the festival period (Fig. 2a). However, in 2013, the cherry blossom festival started earlier than the FFD of *P. yedoensis* and people delayed their spring outing plans even if the blossom festival had started.

As many varieties of peony species were grown at Jingshan Park, the length of the high season (20 d; Fig. S4) was longer than the flowering duration of *Paeonia suffruticosa* (Fig. 2b). The high season and flowering duration of *P. suffruticosa* tracked each other very well. During 2011–2013, the start dates of the peony blossom festival were similar to the FFD of *P. suffruticosa* and the start date of the high season. In 2010 and 2014, the peony blossom festival opened earlier (2010) or later (2014) than the FFD of *P. suffruticosa*, but the spring outing dates of humans were not affected and still tracked the flowering phenology.

The flowering duration of *Malus micromalus* was about 12 d, so the high season was concentrated in a single 10 d period at the City Wall Relics Park (Fig. S5). Among different years (2011–2014), the maximum difference in the start dates of the high season was 20 d. Interannual changes in the high season were almost perfectly consistent with the flowering duration of *M. micromalus* (Fig. 2c).

Since the Summer Palace is a location with multiple ornamental plants, the seasonal variation in the number of visitors was smaller than the parks with specific plants (Fig. S6). The high season (lasting 1 mo) was stable from 2010–2013 but was earlier in 2014 due to an extremely early spring (Fig. 2d).

At the Beijing Botanical Garden, the period with most visitors was commonly April (Fig. S7). Between years, the high season was almost stable (Fig. 2e) and did not change with flowering phenology except for an extremely late spring in 2010.

3.2. Climate impacts on flowering phenology

The flowering dates of our 3 key species (*P. yedoensis*, *P. suffruticosa*, *M. micromalus*) were significantly negatively correlated with preseason temperature ($p < 0.01$), suggesting that earlier FFD and EFD was associated with higher temperatures. The temperature sensitivities ranged from −3.66 to −2.64 d °C^{-1}. The start and end date of the best period for

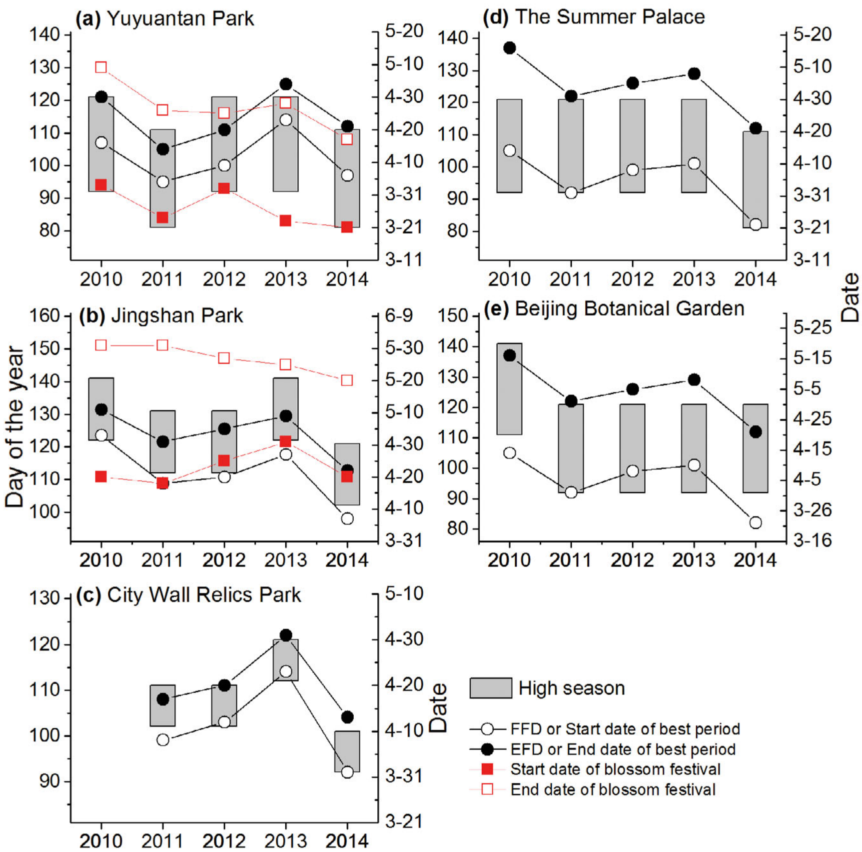

Fig. 2. Relationship between the high season and flowering phenology at 5 locations in Beijing. The high season was compared to first flowering date (FFD) and end of flowering date (EFD) of (a) *Prunus yedoensis* at Yuyuantan Park; (b) *Paeonia suffruticosa* at Jingshan Park; (c) *Malus micromalus* at City Wall Relics Park; (d) spring flowers at the Summer Palace; and (e) spring flowers at Beijing Botanical Garden. Cherry blossom festival dates at Yuyuantan Park and peony blossom festival dates at Jingshan Park are also shown

seeing spring flowers was also significantly correlated with preseason temperature, with sensitivities of −2.79 and −3.34 d $°C^{-1}$, respectively.

4. CONCLUSIONS AND DISCUSSION

This study confirmed that flowering phenophases were very sensitive to small changes in temperature (see also Menzel et al. 2006, Bolmgren et al. 2013, Ge et al. 2015). A 1°C increase in preseason temperature led to an advance of 3.30–3.66 d in the FFD of the 3 ornamental plants we investigated. Thus, the maximum difference in FFD among years would be up to 1 mo. However, few studies have explored whether such variability affects residents' or tourists' spring activity. Based on data from Sina Weibo, we demonstrated that people could perceive climate-induced phenological change, and adjusted their spring outing plans regardless of whether the official blossom festival had opened or not (Fig. 2).

Not only were the people who desired to participate in the blossom festivals sensitive to flowering timing, but the organizers of the festivals or managers of festival-dependent businesses may also be aware of the impact of climate change on the flowering date. One recent study found that some organizers of cherry blossom festivals in Japan were concerned about global warming and its impact on cherry flowering dates (Sakurai et al. 2011). Our study proved that people's visiting dates depend on flowering phenology rather than the blossom festival dates. For example, in 2010, the peony blossom festival of Jingshan Park started 13 d earlier than the FFD of peony. Only a few people visited the park at that time, but more came after the peony FFD when the high season occurred. The difference between the festival period and high season influenced the number of visitors participating in the opening ceremony of the blossom festival and related cultural and recreational activities, which may further impact the commercial benefits of the events. Therefore, blossom festivals should be planned to coincide as closely as possible with the blooming of the plants.

Social media still has great potential in phenological studies. As this study demonstrated, the number of messages related to a specific location can at least partly reflect public attention of this location and the number of visitors. Furthermore, social media is also a source of phenological data. The phenology-related messages posted on social media contained information on the date, place and context in which the observations were made. Although these observations were made by ordinary people or amateur naturalists, the pictures contained in the messages can help experts to define the specific phenophase and assess the reliability of the observations. Such a process of data collection is a valid area of citizen science, which refers to the engagement of non-professionals in scientific investigations (Fuccillo et al.

2015, Scheifinger & Templ 2016). Actually, public participation in phenological research is already quite well established (Elmore et al. 2016, Kobori et al. 2016), and in the future, phenological studies will increasingly benefit if we can extract extensive data from social media.

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